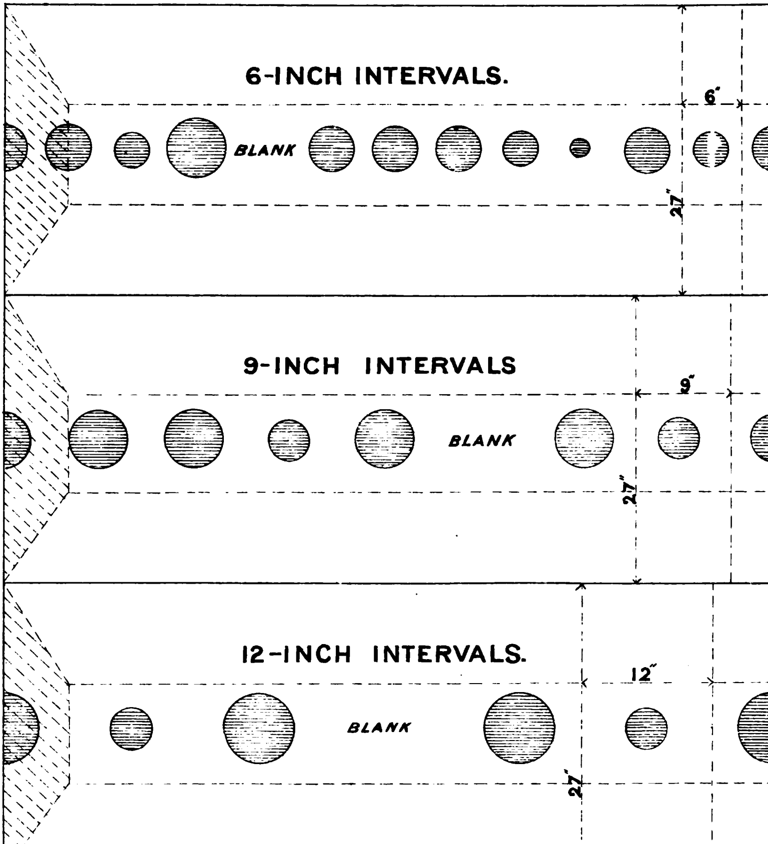
Agricultural Botany

Turnip Singling.



$\frac{1}{18}$

6-INCH 9-INCH 12-INCH

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A CONTRIBUTION

TO

AGRICULTURAL BOTANY:

BEING

LESSONS

FROM

TURNIP SINGLING.

lexand:

BY A. STEPHEN WILSON,

Author of "The Botany of Three Historical Records."

ABERDEEN: JOHN RAE SMITH.

1879.

NOTE.

There are two principles on which, in any given state of Agriculture, the produce of the land may be augmented; (1) increase of cost, and (2) increase of care. In the present condition of the markets, probably, on all our better-farmedsoils, any augmentation of produce, secured by increased outlay, would result in dimiinshed profits. But increased carefulness is necessarily accompanied by augmented profits; and the present papers, reprinted from the *Daily Free Press*, illustrating one example of augmented produce arising from increased attention, may help to recommend the principle thus suggested.

May, 1879.

AGRICULTURAL BOTANY.

TURNIP SINGLING.

Introductory.

A good deal has recently been done towards clearing up our views on certain points in the manuring of the turnip, and I have thought it might be of some interest to inquire in one or two directions in what way the turnip crop ought to be treated, so that manurial improvements might be more fully taken advantage of. A cattle-feeder does not think he has done all that can be done when he keeps his stalls replenished with the best food. He selects the sorts of cattle most easily fed and of most rapid growth. And he treats them in such a way as to make the food given most effective. The agriculturist must act in an analagous way with his turnips. He must not merely supply his seeds with the best manure; he must select the best seeds; he must find out the sorts which grow rapidly to the largest sizes consistent with the heaviest crops. He must give his plants the proper space to grow in. He must use them "as though he loved them."

Even from this pre-eminently turnip-growing country, the glory of discovering the true cause of finger-and-toe has been carried off by a Russian.

M. Woronin has clearly shown that the destructive clubs on our turnip roots are produced by a mere spore-bearing fungus: an organism which never ascends so high in the scale of vegetation as to produce the least particle of stem. Suppose a small puff-ball to burst within your turnip root, to scatter its spores through the tissues, and each spore to produce a new puff-ball, and you have some idea of a part of the genesis of this relentless enemy of the crucifers. Nothing is left for us but the inglorious drudgery of verification; the finding of a few additional facts; and, if it may be, the application of the whole to some theory of a cure.

I offer this slight contribution as an inducement to others, while not neglecting the chemistry of agriculture, to give a simultaneous attention to its botany.

Lessons from Turnip Singling.

There are about 140,000 seeds of common turnips in a pound, or about 20 seeds in one troy grain. When turnip seeds are sown in 27-inch drills at the rate of 3 pounds to the acre, about fourteen times as many seeds are planted as are intended to come to maturity. The weight of the seeds left to grow is about 3¼ ounces. The operation of leaving the plants of these seeds, and cutting out the other thirteen parts, is called singling.

Now, for what purpose is singling performed? It may be done for various purposes. It may be done in order to produce the largest individual plants; or it may be done to produce the heaviest

aggregate of plants. And the question immediately arises—are the two methods of singling here suggested consistent with each other? Can the heaviest possible aggregate be composed of the heaviest possible individual plants?

If 3 pounds of seed are sown at equal intervals on an acre of 27-inch drills, there will be 420,000 plants, each having a space to grow in of little more than half an inch. These plants will each have room to attain a weight of nearly half an ounce, making the total weight upon an acre about six tons. Experience has shown that fewer and larger plants will give a greater total weight. And the question how many fewer and how much larger will give the greatest possible weight? is a purely experimental question, to be answered only by actual experiment.

If, then, a turnip will not attain its greatest size in a lineal space of half-an-inch, there must be a lineal space in which a turnip will attain its greatest size. Let this length of drill, in which, under ordinary profitable cultivation, a turnip will attain its average maximum weight, be called the maximum individual unit. With the largest possible turnips growing at intervals of this unit, the balance will inform us what is the collective weight upon an acre.

The further question then presents itself, can two or more plants be grown within the length of the individual unit, which shall collectively have an equal, or a greater weight, than the plant in this unit? Whether upon trial, this question shall be answered one way or the other, there arises the idea of a maximum collective unit. And as it is conceivable that the heaviest possible individual plants might compose the greatest possible weight per acre, so it is conceivable that the maximum

collective unit might be the same length of drill as the maximum individual unit. But if two or more plants can be grown in the length of the maximum individual unit, which shall collectively be of greater weight than the single plant, then the maximum collective unit is less than the maximum individual unit, and the heaviest crops will consist of turnips less than the largest.

At the beginning of the present century, turnips were frequently sown broad-cast, and were then hoed so as to leave the plants and the rows at equal distances.* And supposing that it should be found profitable in some cases, to return to this mode of cultivation, the units of space here brought under notice, would be reduced to squares, the proper areas of which would have to be determined by experiment.

These units or spaces in which a turnip can grow to its greatest size, or in which it can grow to such size as to form a constituent of the greatest crop, are the chief objects of the present inquiry. They become amenable to scientific treatment, simply because a turnip is a definite product, and will grow only to a certain size. If a turnip would grow larger and larger by allowing it more and more room, any search after the law of a maximum individual unit would be useless. But as a turnip will grow as large upon a square yard as upon a square acre, we see that vegetable laws, put more or less strict limits on the produce of the land, which no manurial effort can overpass.

On the turnip crop of 1877, I made two experiments in singling, in order to find the interval

* Mr Barclay of Ury surpassed all the drilled crops of his neighbours by this method, producing crops of from 30 to 45 tons, the English acre.

which should yield the heaviest return by the acre. In the one case the variety was Greystone Globes, and, in the other, mixed Swedes. The labour and manuring, or the chemical and cultural elements of the question are to regarded as uniform and as not influencing the comparisons.

Performing all the operations personally, I singled on the 20th of July, three equal lengths of adjoining drills, as nearly equal in braird as could be selected. A tape-line was stretched alongside the plants, and drill No. 1, was singled so as to leave the best plants as nearly as possible at distances of 12 inches apart; drill No. 2, was singled to distances of 9 inches apart; and drill No. 3, to distances of 6 inches.

On the 20th and 27th of June, three adjoining drills of swedes were singled in the same way. A length of 120 feet was taken, and 60 feet of drill No. 1 were left with intervals of 12 inches, and also 60 feet of drill No. 3 with the like intervals, but at the opposite end, so as to neutralise any possible difference of soil; 60 feet of drills 2 and 3 were singled to 9 inches, also at opposite ends, and in the same way 60 feet of drills 1 and 2, to intervals of 6 inches.

The singling was done by the hand, and the drills were not reduced by hoeing. Probably both hand hoeing and horse hoeing cut more of the fibrous roots of the young plants than is favourable to their highest growth.

In the operation of singling, it is always impossible to carry the conditions rigidly out. A point comes here and there, in which theoretically a plant should be left, where either no plant exists or a plant of so feeble a growth, that it seems more prudent to leave a better plant, though not quite in the proper place.

Thus the correct number of plants may be left, although not precisely in the points which they would occupy if planted in holes measured out for the experiment. And even where this is done, as in some of the experiments of 1878, the deaths from accident and disease generally thin the ranks and complicate the problem. For, if 100 plants are left at distances of 9 inches apart, which in the course of a week after singling are reduced to 99 by the depredation of a passing crow, the intervals are not 9 inches but something else. This disturbance will be further attended to.

On the 3rd of December the above Greystone Globes were pulled and weighed. The average weight of the plants, including tops and tails, but with all earth removed, was as follows :—

			Average Weight.
Drill No. 1 (12 inch)	...	...	1·70 lb.
„ No. 2 (9 inch)	...	...	1·42 „
„ No. 3 (6 inch)	...	...	1·15 „

The Swedes were pulled on the 17th of December, and, with tops and tails, weighed as under :—

			Average Weight.
Drill No. 1 (12 inch)	...	...	2·50 lb.
„ No. 2 (9 inch)	...	...	1·95 „
„ No. 3 (6 inch)	...	...	1·54 „

It is thus seen that the wider spacing gives the larger turnips; and this obtrusive fact is very apt to obscure the question which is sought to be answered — namely, which interval gives the greatest weight upon the acre?

The drills in these experiments were 27 inches wide, an acre thus extending to a length of 19,360 feet. Where the plants are left 12 inches apart there are thus 19,360 turnips upon the acre; where they are left 9 inches apart there are 25,813

turnips upon the acre; and where they are left 6 inches apart there are upon the acre 38,720. The results, therefore, stand thus :—

GREYSTONE GLOBES.

Interval.	No.	Average Weight.	Total Weight.
12 inch ...	19,360	1·70 lb.	14·29 tons.
9 „ ...	25,813	1·42 „	16·36 „
6 „ ...	38,720	1·15 „	19·88 „
		SWEDES.	
12 inch ...	19,360	2·50 lb.	21·61 „
9 „ ...	25,813	1·95 „	22·47 „
6 „ ...	38,720	1·54 „	26·62 „

It will be here noticed that only the theoretical weights due to the full number of turnips are given. But the theoretical number belonging to any interval seldom comes to maturity. The details of weighing, however, have been lost. The importance of observing and recording all essential particulars only dawns upon an experimenter by long practice.

Thus, then, in the common turnips, so far as these experiments go, the advantage of 6-inch over 12-inch spacing is, upon an acre, 5·15 tons; and the advantage of 6-inch over 9-inch spacing is 3·50 tons. In the swedes the advantage of 6-inch spacing over 12-inch spacing is 5 tons per acre, and the advantage of 6-inch over 9 is 4·15 tons. Or—to state the results otherwise—the same length of drill under the three intervals will produce weights as follow :—

	6-inch inter.	9-inch inter.	12-inch inter.
Turnips	100	82	74
Swedes	100	84	81

The conclusion from these experiments is that intervals of practically 6 inches will produce

heavier crops of turnips and Swedes than intervals of 9 inches or 12 inches.

It is a fact, partly brought out by my experiments on large and small turnip seeds (*Trans. Bot. Soc., Edin.*, 1876-77), that many seeds will produce only a small bulb, however much space they may be afforded. To give such plants 9 inches or 12 inches seems, thus far, to be a wasting of ground. It is to no purpose that chemistry puts manure at the root of a seed which is sterile in the property of bulbing; the botany of that seed, could it be fully read, would point out conditions in the problem not to be neutralised by any application of manure. More plants are wanted, not more manure. The same feeding will not bring all the oxen of a breed to the same bulk; one will claim a first prize, another a second, a third will be commended, while a fourth will be nowhere. Differences of an analagous kind regulate the growth of turnips of a given variety, or of other plants. Our turnip seeds are not to be regarded as mere indifferent starting-points, which, like a gun-ball answering the charge of powder, will go forward the obsequious messenger of some grasping phosphate. A turnip seed is a fully formed plant. It has two leaves tightly wrapped round its root. And within the substance of these two leaves or cotyledons, as they are called, it has a store of milk or pap, needing only to be moistened by water to enable it to start in the world and walk a little without manure of any kind. So long indeed as its own sandwiches hold out most other kinds of food are poison. But no two seeds are alike, or equally furnished for the journey in the drill. And therefore we must study the character and capacity of our little embryos. Some of them have a faultless constitution, and if their disagreeable neigh-

bours were hoed out of the way would acquire the enviable brassical corpulence of eight or ten pounds. Others have a taint of some insidious disease, or the hopes of their youth are obscured by the fly, or their roots are set upon by a myriad of the spores of plasmodia, and thus they may protract a miserable existence under a diameter which would be discreditable to a parsnip. We have therefore to endeavour to find out to what weight the average plant will attain. We have to find out the extent of ground in which a turnip will attain its greatest dimensions. We have to find out whether the greatest individual dimensions are consistent with the greatest crop. And, involved in this, we have to ascertain whether our plants should be permitted to go on to their greatest size, or should be checked at a certain bulk by limitation of the spaces in which they grow. In virtue of certain, presently unknown, properties, some varieties naturally acquire a greater bulk than others; and we have to consider whether our crops, without any additional outlay of manure, might not be augmented by a more general adoption of the most prolific varieties.

II.

The results of the experiments of 1877 go to show that while intervals of 12 inches and 9 inches between the plants produce heavier bulbs than intervals of 6 inches, yet both in the case of common turnips and swedes, intervals of 6 inches produce the greater weight upon the acre.

But as 1877 was a bad turnip season, and as these experiments were on too limited a scale as a

basis for general conclusions, I resolved to institute a more extended series in 1878. Seed of the varieties mentioned in the table below were procured from London and Aberdeen seedsmen. These were used in the experiments in which hand-planting was adopted. In the other cases various locally-grown seed, as they had been sown by the machine, were singled by the hand; adjacent drills being selected for comparison which, at the proper time, showed equality of braird.

The experiments were conducted on seven fields of seven different farms. All the work of planting, singling, numbering, and weighing, was done by myself. Such personal oversight I regard as absolutely necessary for securing accuracy. But I may be excused for saying that honesty is required as well as accuracy, the ultimate appeal in all experiments is not to the figures and averages of a table, but to the moral integrity of the experimenter.

Before proceeding with explanations, or drawing conclusions, I submit the annexed tabulated results. See Tables I. and II.

A few explanations require to be given of these tables. The first column gives the average intervals of 6 inches, 9 inches and 1 link (7·92 inches) left between the plants when they were singled. In those experiments in which the seeds were hand-planted, the tape line was stretched upon the drill, after it had been rolled over with shut boxes, and a small pinch dabbed in between the finger and thumb to a depth of about an inch, at the proper interval, the earth falling in and covering the seed. Where the seed was machine-sown in the usual way, the tape was stretched along the braird, and the intervals left as exactly as the retention of good plants would permit.

The second column gives the percentage of plants remaining capable of being weighed when the crop was pulled. Where 100 appears, of course all the plants left at singling arrived at maturity and came to the balance. Where lower percentages appear such as 90, 85, and so on, the explanation is that a corresponding proportion of the plants left in singling had died in youth and had totally disappeared, or had come to a measure of maturity but were so rotten at the time of weighing as to be unliftable.

The third column gives the average weight of the plants, including tops and tails, free of earth. The proportion of tops and tails varies at different periods; the outer leaves are shed as the season advances. During November and December the tops and tails are about five per cent. of the gross weight.

The fourth column gives the actual weight upon an acre, calculated from the weight actually found upon the length of drills experimented with.

The fifth column gives the weight which the acre would produce if the full and correct number of plants left in singling came to maturity, that is, if they remained in the ground till used for feeding. The drills were all practically 27 inches wide, so that the 6-inch singling gave, as before noted, 38,720, the 9-inch 25,813, and the link 29,333 plants to the acre. These numbers, multiplied by the average weight of plant, give the theoretical weight per acre. It may be noticed that the weighing was done by a Salter's spring balance, with dial of 15 inches, reading to quarter pounds; verified by actual weights before and after use, and a small correction allowed for.

Under the column of "Remarks" will be found the name of the variety of turnip used, where

known; the date of sowing; the date of singling (S.); the date of pulling and weighing (P.), and other circumstances.

The season of 1878 turned out to be very favourable to the turnip crop, and as the results of the experiments of '78 harmonize with the results of the experiments of '77, these results must be regarded as normal facts in the natural history of the turnip.

The experiments of '77, along with certain others which I had previously made (*Expts. with Tur. Seeds, Trans. Bot. Soc., Edin.*, 76-77), convinced me that under the ordinary farm culture of five, six, or seven-year rotations, an interval of 12 inches between the plants, or indeed anything beyond 9 inches, required no further elucidation; 12-inch intervals refused to produce plants double the weight of 6-inch intervals. The ratio of 12-inch to 6-inch intervals stood thus:—

	12 inch intervals.		6 inch intervals.
Common turnips ...	100	to	68
Swedes...	100	to	62

So that while the one 12-inch turnip weighed 100, the two 6-inch turnips weighed 136; and while the one Swede weighed 100, the two which occupied the same length of drill weighed 124.

The experiments of '78 were therefore restricted to intervals of 9 inches, 1 link, or 7·92 inches (practically 8 inches), and 6 inches. Intervals of 8 inches and 9 inches are the intervals in general use in Aberdeenshire; and if it is found that these give the greatest possible weight upon the acre, the farmer has nothing further to learn on the subject of singling a drilled turnip crop; while, if it is found that 6-inch singling gives the greatest

weight, a general practice, disagreeing with such singling, will have to be rationally accounted for.

It is not a chemical question which is here treated, but a botanical, and therefore no account is taken of the various manures used at the different stations. It is assumed, however, that the same manures in the same quantities were applied to the adjacent drills which were compared.

III.

It seems to be generally taken for granted that if the best manure is applied to the soil, the best possible result will arise, as a mere matter of course, without reference to vegetable laws. But manure is applied for no other purpose than that of raising plants. Agricultural plants, like other plants, have certain laws inherent in their constitution. And if we do not plant a turnip seed, for example, at the depth found to be most favourable to the growth of this seed, or if we do not give it that amount of space which, in field culture, is found to develop its largest aggregate return, we may be improving our manurial position by concentrating attention on our chemistry, and neutralising this advance by neglecting our agricultural botany.

The experiments of '78 here reported, varied in length from 30 feet (the length tested by the Annandale Club) to one chain, or 66 feet. Where they were 30 feet, the 6 inch drill contained, at the time of singling, 60 plants, and the 9 inch drill, along side of it, contained 40 plants. Where the experiment was one chain in length, the 6 inch drill contained 132 plants, the link drill 100 plants,

or the 9 inch drill 88 plants. But, as will be seen from the tables, only ten cases occur in which 100 per cent., or the full number of plants left at singling, remained in the ground at the time of pulling.

There was no visitation of fly in 1878. But in a few instances, as I observed, soon after singling the young plant was cut through a little below the surface of the ground by grubs. In a few instances the young plants were plucked up by birds. In two cases a juvenile hoer, not informed of my previous operations, thinned out a few plants after the proper singling had been done, rendering Nos. 7 and 9 of the Swedes less trustworthy than they would otherwise have been. Finger-and-Toe, or Club-root, was more or less prevalent in three fields. In one field it was so virulent that not more than six or eight per cent. escaped the disease. Experiments 9, 10, 11, 12, 13, and 16 of the common turnips were made in this field, and another experiment, in which, however, the destruction was so great that the weights were not compared, nor is it here reported. But as in these experiments the disease had destroyed very few of the plants at an early stage, the roots, though covered with clubs and excrescences, attained an average size, and where not too rotten to be lifted into the weighing net, afforded fair enough comparative tests.*

* I got a complete translation made of M. Woronin's Memoir on Finger-and-Toe or Club-root ("Plasmodiophora Brassicae") by Miss M. Brebner, intending to publish it for the benefit of our farmers. But as M. Woronin's investigations refer almost exclusively to the cabbage, it has occurred to me that the application of his facts to the turnip would be of more extensive use in this

country. I may state, however, that having examined a great many cases of club-root in the common turnips, Swedes, cabbages, and charlock, I have no doubt that the main conclusion of M. Woronin, namely:—that club-root is caused by a vegetable parasite or fungus, is correct. My impression is confirmed by the Rev. M. J. Berkeley who thus writes in the *Gardeners' Chronicle* in Sept. last: "We have great pleasure in stating that Mr A. S. Wilson has recently examined the club-root in turnips, and has completely confirmed the observations of Mons. Woronin. We have ourselves had an opportunity of examining his preparations, which are very satisfactory. The turnips which he sent broke out in every direction with Peronospora parasitica, the common parasite on the leaves of Cruciferae, but we do not suppose that there is any connection between the two fungi, though the matter suggests further investigation. The whole substance of the roots is infested with the parasite, exactly as the tubers of potato are affected by the potato murrain." I may notice, in the meantime, that unless the club-root fungus shall be found capable of taking such a form as the Peronospora parasitica (a mould somewhat like the potato fungus, Peronospora infestans) it is wholly confined within the clubs; being, so to speak, entirely underground, and showing no sort of mould above the skin or surface of the swellings. A piece of pure club root without air-chambers is of a higher specific gravity than the turnips on which it grows, being about 1·031. The clubs or excrescences upon the bulb contain a large proportion of starch grains; but the solid clubs upon the fibrous roots consist almost wholly of the fungus in the form of plasma and globular spores. It will give an idea—the only thing here aimed at—of these spores to conceive of them as a mass of turnip seeds glued together. They are not at all of the nature of a mould growing upon decaying matter. A pure club growing upon a thin root is itself almost

wholly fungoid matter, is perfectly fresh, and will dry and preserve for a long time. The main feature of the disease, which may be seen without trouble at any time, and which any farmer with an ordinary microscope may examine for his own satisfaction, is the multitude of spores of which the clubs consist. If the side of a fresh club be sliced off, and the least scraping taken from the interior and placed in a drop of water on a glass slide, under a piece of thin glass, the spores may be seen lying in vast shoals. "The number of spores," says M. Woronin, "is excessively large. The individual spores are remarkably small, their greatest diameter does not exceed ·0016 mm. They are as a rule quite spherical." It is a curious fact that all those which I have measured, and they are all very nearly of one size, are about three times the size assigned to them by M. Woronin, namely of a diameter of ·0044 of a millimetre, or ·00017 of an inch. Perhaps they attain to a larger size in Scotland than in Russia. Taking my measurement, 5840 of these tiny balls can lie side by side on a lineal inch; 34 millions on a square inch, while a cubic inch contains 199 billions. A soil saturated with seeds of disease so numerous is probably to be cleared only by one method. All seeds and spores have a certain peculiar duration of vitality. An oat seed or a wheat seed, however well preserved, will not in general germinate beyond the fourth or fifth year. And the probability, as it seems to me, is that the spores of club-root will die if not allowed to reproduce themselves in a certain, at present unknown, number of years. If the turnip crop in a seven-year rotation is less liable to club-root than in a five-year rotation, there is probably no other mystery about this than simply that in seven years a greater number of spores die out than in five years.

I mention these various circumstances which detract from the value of the present experiments,

because, where facts which influence the results are concealed, the experiments are worthless. Only those who have engaged in such or kindred investigations have any idea of the hosts of antagonistic agencies which enter the field with distorting complications. In an experiment in which the full number of plants reach a healthy maturity, such as No. 7 of Table 1, no sort of correction can require to be made in respect of blanks, while in such an experiment as No. 1, Table 1, where the full number of plants do not reach maturity, if the proper correction cannot yet be made, an element of error, or at least uncertainty, is involved. It is seen from the tables that even where there is no virulent club-rooting, only about 94 or 95 per cent. of the plants left at singling in the 6-inch intervals remain to be pulled, and about 97 per cent. in the 1-link and 9-inch intervals. Now, as these blanks must leave some of the intervals more than the proper length, the question has to be answered—What is the effect of these increased intervals on the weight of the crop to be tested? Are the plants immediately on each side of a blank heavier than those in succession along the drill, or are they lighter? It might be thought that as 12 inch intervals will give heavier plants than 6 inch, all blanks in 6-inch and 9-inch spacing will show heavier than average bulbs at either end. Observation, however, shows that this may be the case or may not. In 115 blanks taken at random in a field of Swedes—

22 per cent. showed adjoining bulbs larger than the next following.
44 per cent. „ smaller „
34 per cent. „ same as „

And in 118 blanks taken in a field of Yellows :—

24 per cent. showed adjoining bulbs larger than the next following.			
36 per cent.	,,	smaller	,,
40 per cent.	,,	same as	,,

So that probably the cause of the blank, were it known, would explain the size of the bulbs beside it. If there has been an accidental blank in the manure, or if the spot contains hostile ingredients, or if the seed has been too deeply deposited, or deposited amongst dry and unbroken clods—the blank has arisen from causes fatal to the young plant; and as these causes will extend a short way on either hand, the adjoining bulbs will be smaller than those in succession. If a blank has been caused where no element of nutrition was awanting, by careless hoeing, the cutting of a grub, or the plucking of a bird, the bulbs adjoining it will probably be larger than those following. Or if a blank is caused by disease and subsequent rotting, after the bulb is considerably advanced, the plants on each end of it may be a little different from others along the drill. The point is further complicated by the comparative size of the seeds which have produced the bulbs adjacent to the blanks.

It may be noticed here that when a blank of one plant occurs at an early stage in 6-inch intervals, the bulbs on each side may go in search of food for a distance of 6 inches in the open drill, and the fact that in 12-inch singling the bulbs attain about their maximum size, shows that the fibrous rootlets can carry to the bulb sensible quantities from a distance of six inches, when growing surrounded by others. But when a blank occurs in 12-inch singling the plants on each side

derive no practical benefit from the empty space; the fibrous roots cannot carry additions of appreciable importance to the bulb from distances beyond six inches. No doubt rootlets run out very much further than six or twelve inches, but frequently, and especially in Swedes, these rootlets, instead of carrying to the bulb whatever materials they lay hold of, store it up in themselves, becoming what are called tails, and which are cut off and left upon the ground. It is thus seen that when blanks occur in 6-inch singling, not by mineral poisoning, but by accidents of sowing, hoeing, or depredation, they may be partly neutralised by the possibility of extra growth in the plants adjoining them; while when blanks occur in wider intervals less proportionally of the loss is made good by extra growth, the plants having already nearly all the space from which they can collect food.

But in the results given in the tables no corrections have been made in respect of blanks. Without the information necessary to form a principle such corrections would have been empirical and deceptive.

In experiment No. 1, Table I., the seeds were hand-planted in tufts at the intervals of 6 and 9 inches, and the plants were singled when very small, to test whether such early thinning would or would not be an improvement. The result shows (so far as it goes) that singling when the plants are very small and not sure of their hold, ought not to be practised. Of the 6-inch plants, 18½ per cent. died before they were long out of their cotyledons, and of the 9-inch plants 7½ per cent. The 6-inch intervals thus became, on an average, 7.35 inches, and the 9-inch intervals became 9.73 inches. The average plants in both drills are therefore a little heavier than they would

have been had all the plants come to maturity. And since the 6-inch interval was more increased than the 9-inch, it is clear that a proper correction would reduce the weight (1·94 lb,) of the 6-inch plants more than the weight (2·68 lb.) of the 9-inch. But while the increased intervals augmented the size of the bulbs, the premature singling diminished the size. Under these complications any correction which might be proposed would be too uncertain to have a practical value. The "actual weight" on the 6-inch intervals is seen to be less than on the 9-inch intervals; but the "theoretical weight," that is the weight assuming the full numbers of 38720 and 25813 plants respectively upon the acre, is greater on the 6-inch than on the 9-inch intervals. And if the higher per centage of 92½ had come to the balance in both drills, the "actual weight" on both intervals would have been equal.

Again, the low per centage of plants which remained to be weighed in Nos. 9, 10, 11, 12, 13, and 16 of the first table was due to finger-and-toe or club root. Six years ago, when the field in which these experiments were made was in turnips, this disease, or rather attack of one plant by another, proved fatal to a large proportion of the seedlings at a very early stage; but in '78 the growth of the plants which were too rotten to be ponderable at the date of weighing, was so rapid that a great part arrived at comparative maturity before being destroyed. And this fact gives these experiments a greater value than they would have had if these plants had died while young; because the plants which remained to be weighed had grown in the intervals which were to be compared. In Nos. 9 and 10 the actual weight on the 9-inch intervals

is greater than on the 6-inch; and in 11, 12, 13, and 16 the actual weight on the 6-inch intervals is greater than on the 9-inch. But in all these six cases the theoretical weight is greatest on the 6-inch intervals. In other words, if the same percentages had been carried off by disease in both drills, then in all cases the actual, as well as the theoretical weights, would have been greatest on the 6-inch intervals.

The inductive value of Nos. 7, 8, 9, and 10 in the second table is also somewhat diminished by an accidental hoeing out of plants and destruction by grubs. In these cases the plants which survived had more than the original intervals during most part of their growth. In weighing from the 6-inch intervals here, those plants only were taken which had grown nearest to the proper distance; while all the plants left in the 9-inch drills were weighed, on the assumption that the increase of interval in their case would not add very much to the average weight. No. 8 gives a higher theoretical weight upon the acre for the 9-inch interval than for the 6-inch; but as the average intervals were really increased to 14 inches, the average weight of the plants should properly be multiplied —not by the number for 9-inch intervals (25,831) —but rather by the number for 14 inches, or say 12 inches (19,360), thus making the theoretical weight not 36·07 tons, but 31·22.

Probably in these four experiments the average weight given for the plant in the "6-inch" intervals is rather more than 6-inch intervals would have produced. But I do not think that any legitimate correction would reduce the theoretical weight upon the acre from the 6-inch intervals below the weight from the 9-inch intervals.

With these explanations and qualifications, the experiments seem to afford a fair comparison of the value of 6-inch intervals with those of 9 inches, or of 1 link. Candour demands that all the circumstances which introduce uncertainty, or overcloud any of the results with doubt, should be distinctly avowed to the best of the experimenter's knowledge. For it may be safely taken for granted that the line of research will always meet with disturbances of which he has no knowledge whatever. And when experiments once get themselves dressed in arithmetic, they usually strut forth with an air of truthfulness and importance which their real antecedents would not fully warrant.

These experiments, however, show such uniformity as hardly leaves any doubt that in general 6-inch intervals will ensure a heavier crop of Swedes or of common turnips than intervals of 8 or 9 inches. No. 6 of Table 1 is the sole case in which both the actual and theoretical weights are greater upon the acre from 9-inch intervals than from 6-inch. But as Nos. 2, 3, 4, 5, and 7 of the same table were in the same field, and close beside No. 6, and all give a verdict in favour of 6-inch intervals, No. 6 can only be regarded in the light of an exception to the general rule.

In the case of common turnips, the general average shows that 6-inch intervals gave 28·64 tons of actual weight upon the acre, and would have given 31·88 tons had there been no blanks in the crop; while 8 and 9-inch intervals gave an actual weight of 26·61 tons and a theoretical weight of 28·78 tons. The actual weight was 2 tons in favour of 6-inch intervals, and the theoretical weight rather more than 3 tons.

In only one case, No. 2, Table II., did the Swedes give a greater actual weight for 9-inch

spacing than for 6-inch, the reason clearly being that while 100 per cent. of the 9-inch came to the balance, only 94 per cent. of the 6-inch came. And, as in this experiment the theoretical weight of the 6-inch is greater than that of the 9-inch, the 6-inch turnips are, of course, heavier in proportion to their space than the 9-inch. In all the other complete experiments, both the actual and theoretical weights are greatest on the 6-inch intervals. The 6-inch intervals gave an actual acre-gift of 25·48 tons, and a theoretical of 31·60 tons; the 8 and 9-inch spacing giving an actual weight of 24·22 tons, and a theoretical weight of 26·52 tons. The actual crop was a ton and a quarter in favour of 6-inch intervals, while, if all the plants left in singling could have been matured, the weight in favour of 6-inch intervals would have been five tons.

IV.

The proportionate weight which a turnip in a 6-inch interval must bear to a turnip in a 9-inch interval, in order that both crops may be equal, is two-thirds; and where the comparison is between 6-inch and 1-link intervals, equal crops require that the plants in the 6-inch intervals shall weigh seventy-six hundredth parts of the plants in the link intervals. Or conversely, equal crops are secured where the average plant in the 6-inch interva's weighs 100; in the link intervals 132; and in the 9-inch intervals 150.

The following tables show the relationships in our experiments of '78 in both aspects. The 6-inch plants are made the datum on one side and

the link and 9-inch plants on the other. The link and 9-inch plants are given in percentages of the 6-inch plants for each experiment, and also (for the convenience of those curious in the subject) the 6-inch plants are given in percentages of the link and 9-inch plants.

III.—COMMON TURNIPS.

Proportionate weights in 6-inch, 1 link, and 9-inch intervals:—

	6-inch intervals.	9-inch intervals.		9-inch intervals.	6-inch intervals.
Equal Crops	100	150	Equal Crops	100	67
Experiment 1	100	138	Experiment 1	100	72
,, 2	100	144	,, 2	100	69
,, 3	100	134	,, 3	100	75
,, 4	100	147	,, 4	100	68
,, 5	100	119	,, 5	100	84
,, 6	100	154	,, 6	100	65
,, 9	100	148	,, 9	100	68
,, 10	100	138	,, 10	100	73
,, 11	100	11[illegible]	,, 11	100	86
,, 12	100	144	,, 12	100	69
,, 18	100	134	,, 18	100	75
Average	100	138	Average	100	73
	6-inch intervals.	1 link intervals.		1 link intervals.	9-inch intervals.
Equal Crops	100	132	Equal Crops	100	76
Experiment 7	100	127	Experiment 7	100	79
,, 8	100	125	,, 8	100	80
,, 13	100	112	,, 13	100	89
,, 14	100	99	,, 14	100	101
,, 15	100	103	,, 15	100	97
,, 16	100	12[illegible]	,, 16	100	82
,, 17	100	113	,, 17	100	89
Average	100	114	Average	100	88

IV.—SWEDES.

Proportionate weights in 6-inch, 1 link, and 9-inch intervals:—

	6-inch intervals.	9-inch intervals.		9-inch intervals.	6-inch intervals.
Equal Crops	100	150	Equal Crops	100	67
Experiment 2	100	143	Experiment 2	100	70
,, 3	100	140	,, 3	100	72
,, 5	100	121	,, 5	100	83
,, 7	100	102	,, 7	100	98
,, 8	100	160	,, 8	100	63
,, 9	100	94	,, 9	100	106
,, 10	100	123	,, 10	100	82
Average	100	126	Average	100	82
	6-inch intervals.	1 link intervals.		1 link intervals.	6-inch intervals.
Equal Crops	100	132	Equal Crops	100	76
Experiment 1	100	121	Experiment 1	100	82
,, 4	100	118	,, 4	100	85
,, 6	100	116	,, 6	100	86
,, 11	100	120	,, 11	100	84
Average	100	119	Average	100	84

Explanation.—"Equal Crops" means that where the average turnip in 6-inch intervals weighs 100 parts, and in 9-inch intervals 150 of the same parts, or, in link intervals 132 parts, the weights per acre will be equal. Or, where the average turnip in 9-inch intervals weighs 100 parts, and in 6-inch intervals 67 of these parts; as also where the turnip in link intervals weighs 100 and in 6-inch intervals 76, the acre-gifts are equal. By comparing these figures with the proportions in the various experiments, it is seen at a glance how much any one crop exceeds or falls below that with which it is compared.

In examining these tables let it be recollected that with 27-inch drills there are, at 6-inch intervals, 38,720; at 1-link intervals, 29,333; and at

9-inch intervals, 25,813 plants possible upon the acre. So that if the 6-inch plants weigh 100, the link plants 132, and the 9-inch plants 150, the three crops will be of equal weights, thus :—

38,720	29,333	25,813
100	132	150
3,872,000	3,872,000	3,872,000

If now the column of 9-inch intervals in Table III. be run over, it will be noticed that only in one experiment, No. 6, does the percentage rise above 150. In all the other cases it falls below this number, the average being 138, and thus showing that the plants in the 9-inch intervals are proportionately lighter than those in the 6-inch intervals, to the extent of 12 per cent. In none of the 1-link intervals does the average plant show the percentage of equal crops. The average per cent. is 114, falling 18 parts of the 6-inch plants below equality of crop.

In the case of the Swedes (Table IV.) the percentages in all the experiments, except No. 8, both 9-inch and 1-link intervals, show that the wider spaces carry relatively less weight than the narrow. The 9-inch intervals fall 24 per cent., and the link intervals 13 per cent. below the level of a crop equal to that of the 6-inch intervals.

I have thus satisfied myself that, in crops of many usual sorts of turnips in considerable variety of soils, in favourable and unfavourable seasons, under ordinary rotations of cropping, six-inch intervals will give a heavier crop than any wider intervals.

Whether it is advisable to adopt these smaller intervals is left for farmers themselves to determine. The law of compensation is wiser than a policy of ephemeral selfishness. There are two

modes of treating the land, which may be abstractly termed the exhaustive and the conservative. If 6-inch intervals are substituted for something wider, the singling will (on the drill system) cost a little more. The manure will be more fully exhausted by the turnip crop. With a heavier crop of turnips, probably a lighter crop of corn will follow; and with a more or less prolonged succession of heavier turnip crops, there must be induced a degree of exhaustion. A cultural administration which secures a high and permanent supply of the raw materials of human life recommends itself to the nation and to the permanent possessor; while to the temporary possessor in his official capacity, that administration is the best which secures the highest temporary return.

It is not very easy to determine whether the weight of an acre of turnips has increased or diminished in Aberdeenshire during the present century. Some facts are given in Dr Keith's report (*Agriculture of Aberdeenshire*, 1811), but they scarcely suffice for a general conclusion. A weight of twenty-eight and a half tons on the English acre is there given as a probable average. Of nineteen weighings made by Dr Keith, the average was 34·6 tons; but he adds that the crops tested "were much superior to the average of the county in 1809, for the fly was very destructive and the reporter went to those places which had escaped its ravages."* (*Agr. of Abd.*, *p.* 288)

Dr Anderson, writing in 1794, tells us that the general average crop of turnips in Aberdeenshire is as high as in any part of the island, the plants being at least double the size of those reared in Norfolk (*Gen. View of the Agr. of Abdn.*, *p.* 65).

* It is remarkable that club root does not seem to have existed at the date of Dr Keith's report.

Dr Keith speaks of the drills being 26 and 27 inches wide, and the singling as showing intervals of 8, 9, and 10 inches. He had ascertained that "when turnips are of too large a size they are seldom able to endure the frost in winter; and not only the specific gravity of the bulb is less, but the crop is not so weighty on an acre. He uniformly found the greatest crop per acre where the drills were from two feet three to two feet six inches, and where the turnips weighed on an average four pounds avoirdupois" (*Rep. p.* 284.)

But do the facts thus given by Dr Keith harmonise? Is it possible that crops of turnips grown upon 27-inch or 30-inch drills, and with intervals of 8, 9, or 10 inches, can show an acre-gift of from "28" to "34" tons, with individual plants averaging a weight of 4 pounds? With 27-inch drills, intervals of 8 inches, and plants averaging 4 pounds, the acre carries 51·86 tons; with 9-inch intervals, 46·09 tons; and with 10-inch intervals, 41·49 tons. If the drills are 30 inches wide, 4-pound plants with 8-inch intervals give a weight of 46·67 tons; with 9-inch intervals, 41·49 tons; and with 10-inch intervals, 37·34 tons.

Apparently there was no finger-and-toe in the early part of this century; and, therefore, if we suppose the two smaller of these totals to be reduced by birds and grubs about three per cent., the 27-inch drills with 10-inch intervals and average plants of 4 lbs., will still show an acre-weight of 40 tons, and the 30-inch drills a weight of 36 tons. And as Dr Keith is more likely to have erred in regard to the average weight of the plants than in regard to the weight upon the acre, we may be certain that the average turnip, under the conditions specified, never weighed nearly "4 pounds."

Freedom from prejudice is required to test the average weight of a turnip. You begin to pull and the first few are good round bulbs and you think these will give a high average weight. You then encounter one not much thicker than your finger, and although it occupies as much space as one of the larger, you throw it aside, with the reflection that it is no turnip at all, a mere abortion not worth counting. But this will not do. You must resolutely count and weigh every one, in order to find the average weight on any turnip-unit of land. It must have been by rejecting the stunted bulbs that Dr Keith found an average of 4 pounds.

The following tables show the percentages of the various sizes of green-top-yellow and Swedes, on good and well-manured land in ordinary rotation; the yellow showing a total acreage of about 29 tons, and the Swedes a weight of about 28 tons.

V.—YELLOW TURNIPS.

Proportion of different sizes, crop 1878.

Per Cent.	Size.	Average Weight.
12·5	Under 3 inches diameter	·53 lb.
25·5	Above 3 in. and under 4 in.	1·38 ,,
36·5	,, 4 ,, 5	2·26 ,,
16·5	,, 5 ,, 6	3·22 ,,
7·0	,, 6 ,, 7	4·48 ,,
1·5	,, 7 ,, 8	5·00 ,,
·5	,, 8 ,, 9	8·50 ,,
100	Average weight	2·205 lb.
	Average interval	7·77 in.

Other parts of this field gave results slightly

different. The average of several enumerations showed the following percentages :—

Under 3 inches diameter	...	14·4	per cent.
Between 3 and 4 inches	...	27·4	,,
,, 4 ,, 5 ,,	...	28·1	,,
,, 5 ,, 6 ,,	...	22·1	,,
,, 6 ,, 7 ,,	...	8·0	,,

And giving an average diameter of about 4·24 inches.

VI.—SWEDES.

Proportion of different sizes, crop 1878.

Per Cent.	Size.	Average Weight.
22	Under 3 inches diameter	·65 lb.
32	Above 3 in. and under 4 in.	1·43 ,,
20	,, 4 ,, 5	2·51 ,,
19	,, 5 ,, 6	3·20 ,,
7	,, 6 ,, 7	5·25 ,,
100	Average weight	2·08 lb.
	Average interval	7·74 in.

Several other enumerations, where the intervals were 8 and 9 inches, gave the following percentages :—

Under 3 inches diameter	...	15·7	per cent.
Between 3 and 4 inches	...	30 5	,,
,, 4 ,, 5 ,,	...	27·5	,,
,, 5 ,, 6 ,,	...	17·8	,,
,, 6 ,, 7 ,,	...	8·5	,,

And giving an average diameter of about 4·15 inches.

It is thus seen that with an interval of about 8 inches, which is probably the customary interval in Aberdeenshire, the average diameter of green-top yellow turnips is about 4¼ inches, and of Swedes about 4 1-7th inches. And it is likewise seen from these tables, and from the foregoing ex-

periments, compared with the returns of local field competitions,* that the average weights upon the acre in the various districts of the county are attained through individual plants averaging about 2 pounds. If a crop of 29 tons, as above, is attained by average plants of 2 1-5th lbs., Dr

* A few facts, deduced from the reports of the Warthill Turnip Club, may save the reader some trouble. The first prize Swedes of crop 1878 weigh 23·64 tons per acre. The drills are 27½ inches wide, so that the length of drill to make an acre is 19,008 feet. There is thus upon the lineal foot a weight of 2·79 lbs.; and if the singling averages 8 inches, the turnip averages 1·86 lb. The first prize yellows weigh 22·86 tons. The drills being 26½ inches, the length of the acre is 19,913 feet, each foot carrying 2·57 lbs., and giving for 8-inch singling a bulb of 1·71 lb. The average weight on the running foot of six farms which get prizes for Swedes in '78 is 2·47 lbs., giving to 8-inch singling average bulbs of 1·65 lb. The average on the foot of yellows is 2·36 lbs., 8-inch intervals giving bulbs weighing 1·57 lb. each. The average of Swedes and yellows of the first class over thirteen farms examined for the crop of '78 is 19·64 tons. This weight gives about 2·25 lbs. of turnips to the lineal foot; and if the singling is generally 8-inch, the plants average 1·50 lb. The average weight of Swedes and yellows of the first class for nine years is 18·50 tons. This total gives a weight on the running foot of about 2·14 lbs., a bulb for 8-inch singling of 1·43 lb., and for 6-inch singling of 1·07 lb. It thus appears that there are good districts of Aberdeenshire—a shire not inferior to any in Scotland for turnips—in which the average bulb is less than a pound and a half; and in which the running foot of drill does not carry two and a half pounds of brassical food. Surely by a little consideration, and without additional cost, something may be added to this.

Keith's average of about 28 tons, as already observed, did not require bulbs of 4 lbs., and consequently his average for single plants must be much over-stated.

V.

Whether in different parts of the kingdom, different intervals would give the heaviest crop, might be worth the trouble of further investigation. No doubt some experiments and opinions are already to be found on the subject in the agricultural records; but experimental work has seldom been sufficiently guarded to be altogether trustworthy.

I shall make a few remarks on the tables and reports of the Annandale Turnip Society (*Trans. of Highland and Agr. Soc., new ser., nos.* 28, 32, 36, 52). From these we learn that it was the practice on the farm of Hardgrave to drill at widths of from 25 to 29 inches, to single Swedes to intervals which give an average of 13·5 inches, and common turnips to intervals averaging 13·22 inches. Large quantities of various manures were applied, and heavy crops were raised. And the reporters for the years under notice approve of wide intervals. In the report on the crop of 1850 it is said, "The precedent of thin hoeing of last year attracted general attention; and on six or eight farms where the greatest produce is shown, the turnips are all at eleven to thirteen or fourteen inches apart, while in most of the smaller crops they are only at seven or eight inches; and where experiments have been tried in the same field the weight is greatly in favour of thin hoeing, as far at least as thirteen or fourteen inches. It is only, therefore, in the case of poor land, late sowing, or

scanty manuring, that the inspectors would hesitate to adopt thin hoeing; and even in such exceptional cases they have yet to see more experiments made, and seasons of a different character from the present one, before they would pronounce against it even then; and they may further remark that the advantage of thin hoeing has been more decidely proved to them in regard to Swedes and white turnips than in the case of yellow bullock, of which there have not yet been shown many examples of thin hoeing to compare with the ordinary mode." (No. 32, 1851, pp. 517-18.

It will be noticed that this is mostly an expression of opinion; and where it is said that experiments in the same field proved the superiority of thin hoeing, no particulars of the test are given, nor any measure of the superiority. The present experiments do not afford a basis for comparison with those of Hardgrave. Such a basis requires the same season, the same soil, the same manure, the same seed, the same treatment, the same experimenter. It will nevertheless be instructive to compare the Hardgrave singling with the Newmachar, in order to see which has gained the best absolute results. The following table gives the results of the two modes of singling:—

VII.—Results of Singling at Hardgrave and Newmachar.

SWEDES—AVERAGES.

	Width of Drill.	Interval	Number of Plants.	Average Weight of Plants.	Wt. per Acre.
	In.	In.		Lbs.	Tons.
Hardgrave	27	13·5	17,209	3·85	29·60
Newmachar	27	6	38,720	1·83	31·60

SWEDES—HEAVIEST CROPS.

	Width of Drill.	Interval	Number of Plants.	Average Weight of Plants.	Wt. per Acre.
	In.	In.		Lbs.	Tons.
Hardgrave	27	12·36	18,796	4·28	35·20
Newmachar	27	6	38,720	2·21	38·20
COMMON TURNIPS—AVERAGES.					
Hardgrave	27·66	13·22	17,164	3·37	25·30
Newmachar	27	6	38,720	1·84	31·88
COMMON TURNIPS—HEAVIEST CROPS.					
Hardgrave	28	13·32	16,818	4·16	31·20
Newmachar	27	6	38,700	2·90	50·04

The Hardgrave Swedes are the averages of seven experiments, the Newmachar Swedes the averages of eleven. The Hardgrave common turnips are the averages of thirteen experiments, the Newmachar turnips the averages of eighteen. But from the Newmachar weights are to be deducted 5½ per cent., being the weight of tops and tails, which are not included in the weights at Hardgrave. When this proportion has been deducted, it will be found that the 6-inch intervals carry the greatest crops. In Swedes, the average Newmachar 6-inch unit carries a weight of 1·83 lbs., or without tops and tails 1·73; and in order that the Hardgrave unit of 13·5 inches should produce a crop of equal weight, it should carry a plant of 3·89 lbs., while it carries one of 3·85. In common turnips the Newmachar 6-inch unit, without tops and tails, carries a weight of 1·74 lbs., and in order that the Hardgrave unit of 13·22 inches should carry an equal crop, its bulb ought to weigh 3·83 lbs., while it weighs only 3·37.

In 1878, with intervals of 9·22 inches, the Alford Turnip Club produce an average Swede of 2·05 lbs., the crop being 23·20 tons. The greatest

weight is from intervals of 9·68 inches, being 25·85 tons. Intervals of 10·44 inches give 24·72 tons, and also 2 tons less. Common turnips, with average intervals of 9·18 inches, give a bulb of 2·01 lbs., and a crop of 22·74 tons. The greatest weight is from intervals of 8·44 inches, being 25·85 tons. Where the interval is 11·52 inches, the bulb is 2·38 lbs., and the crop 21·50 tons.

By the kindness of Mr Carnie, I have before me the Reports for the last three years of the Ontario School of Agriculture; and the following facts from Prof. Brown's department are interesting in the present connection :—

With drills 30 inches wide and intervals of 12 inches, the heaviest crop of turnips in 1876, with farm-yard manure, was 11·5 tons. But in 1877 there is a great advance. With the same singling and drilling, the average bulb of thirteen varieties weighs 4 lbs., and the average "full crop" (here called *theoretical crop*), is stated at 34½ tons, the Canadian ton being 2000 lbs., the crop thus weighing 30·8 imperial tons. The actual crop, however, was "one third less," making the yield about 20 tons. In 1878 the average weight of Swede in thirteen varieties is 2·65 lbs. The drilling and singling are such that 15,600 plants are left upon the acre, making a unit of 402 square inches. But the average number of plants grown is only 8610, the average number of blanks being 6990. Thus the actual average crop is 10·19 imperial tons, and the theoretical crop 18·40 tons. The results in three experiments are given of sowing on "the flat," and in drills at distances apart of 14 by 12, 18 by 9, and 27 by 6. On the flat 14 by 12 is best, and in drills 14 by 12 and 18 by 9 are equal. It is stated by Professor Brown, that this experiment has been tried in

Scotland, showing a tendency in favour of the "smaller area allowed to each root." But here the area or unit is practically the same in all the three cases, and what seems proved, apart from the difficulty of working, is that a better crop results from placing the plants in the centre of a square unit than in the middle of an oblong unit, as in common drilling. About 11 tons were produced from intervals of 14 by 12, a unit of 168 square inches; while the main crop of thirteen varieties of Swedes with a unit of 402 square inches, shows an actual crop of 10 tons.

The cause of the great number of blanks in the Canadian crop of 1878 is not stated, but the result is that a weight of 2·65 lbs. is produced upon an actual area of 729 square inches, and an actual number of plants of 8610 upon an acre. In our experiments with Swedes, the blanks from all causes reduce the number on the 6-inch intervals from 38,720 to 35,084; so that a weight is produced of 1·83 lbs. upon an area of 179 square inches, being about three times as much as is produced on the Experimental farm at Guelph. Vegetable conditions and limitations in each country must be studied in the proper place. That we had a few schools of Agriculture, similar to the college at Guelph, in various parts of this country, is much to be desired.

It may be here noticed that with 6-inch intervals, bulbs of 6 inches in diameter are possible, and by the laws of the plant, may actually grow. Bulbs of this size weigh about 3·35 lbs., making the utmost possible weight per acre with 27-inch drills, 57·90 tons; while the weight of Swedes of 6 inches diameter being about 4·20 lbs., the possible weight per acre is 72·60 tons. But the less demand that is made upon a bulb, the more sure will be the re-

sponse. Mr Barclay is said (*Agr. Survey. Kincardineshire*, p. 337) to have singled his broad-cast turnips to distances of 12 inches each way. He had thus 43,560 turnips, not deducting blanks, upon the English acre. And as he had crops of from 30 to 45 tons, his plants averaged from 1·54 to 2·54 lbs. I propose to make such experiments as shall show the size of square units producing the maximum weight of single plants, and the maximum weight of single plants yielding the maximum aggregate. There is no necessity that plants grown in this way should be sown broad-cast; a machine could easily be devised for sowing in lines without drills, at such distances apart as may be found requisite for the most fertile size of the collective square unit.

But it is a fact which, although well known, is less kept in view than it should be, that under the same circumstances, different varieties of turnips will attain very different average sizes. And probably agriculture has more to expect from the better-bulbing varieties of turnips than from improvements in manure; for, while more effective manures will generally cost more money, the seed of a variety of turnip, the bulb of which averages three pounds, is as cheaply raised as the seed of a variety whose bulb averages two pounds. But the present experiments afford scarcely any facts for determining the most productive varieties of turnips. And again, the adoption of the most productive is a problem complicated by such questions as these—Are the most productive the most capable of resisting frost and rotting? Are all varieties equally liable to club root? Are the most productive the most nutritious? Or, if the most productive are not the most nutritious, weight for weight, will the total weight of the most pro-

ductive out-value the total weight of the most nutritious? What variety will send the greatest value to the feeding trough?

VI.

We see from the facts before us that our *best* average agriculture has certainly not got beyond $3\frac{1}{2}$ pounds of turnips upon the lineal foot, or about $1\frac{1}{2}$ pound upon the square foot. Is it possible to over-pass this limit? Would higher profits arise by attempting to over-pass it? This is not a mere question of manure and chemistry; the turnip itself has got something to say in the matter. No amount of feeding would avail to produce men averaging six feet high. No amount of manure, profitably or prodigally applied, will produce barley stalks carrying an average of forty grains. And although, at first sight, the law of bulbing in turnips seems somewhat indefinite, giving a range of from a few ounces to twenty or thirty pounds, yet when we see the law applied to turnips growing socially as crops, we find that it is much more strict. Each plant cannot be allowed to attain to the utmost dimensions of which individually, and growing solitarily, it would be capable, but only to the dimensions which are consistent with the greatest aggregate weight.

Whether manure of any kind, found or to be found, can increase the average plant of any given variety beyond what the best cultivation has already arrived at is not a botanical question, and does not therefore fall to be here considered. Our average plant in 6-inch intervals for the present series of experiments is 1·84 lb. The heaviest

average of any variety in the same intervals is 2·90 lbs., and is given by the variety here called Lincolnshire Red Globe. Of course, the conditions were not the same in all the experiments, and therefore a full comparison of all the so-called varieties cannot be made. But the varieties in Nos. 2, 3, 4, 5, 6, and 7 of the common turnips were tested under circumstances which enable a tentative inference to be drawn. The seeds of Nos. 2, 3, 4, and 5 were procured from a London seedsman, and I do not know their age or history. The seeds of 6 and 7 were home-grown and a year old. In the order of weight in the 6-inch intervals these varieties will stand thus—

	Lb.		T. per Ac.
7. Green-top-yellow	1·66	—	28·69
6. Do.	1·91	—	33·02
3. Champion Purple-top	2·07	—	35·78
2. Imperial Green Globe	2·23	—	38·55
4. Purple-top Mammoth	2·51	—	43·39
5. Lincolnshire Red Globe	2·90	—	50·04

Here, then, we have large differences, not due to differences of soil or to differences of manure, but due simply to differences of productiveness in different varieties of the turnip.

If we suppose, upon the data here stated, that for the whole of Scotland Lincolnshire Red Globe is substituted for green-top yellow, in common turnips, the gain is about seven million tons. No doubt many questions have to be tested before any such nominal gain can be reduced to its true value. But that for all feeding purposes 50 tons of Lincoln red are better than 30 tons of green-top yellow is beyond doubt.

There are also probably other methods besides the selection and improvement of productive varie-

ties, and altogether apart from the manurial department of cultivation by which the average crops of turnips may be augmented. Dr Brown mentions in his *Manual of Botany (p. 525)* that Mr Oliver of Lochend, near Edinburgh, found that "two-year-old turnip seed produced larger bulbs and less leaf than fresher seed." It is not stated on what experiments this conclusion is based; and as seeds of one year old cannot be grown alongside of the same seeds two years old, in the same season, such a conclusion must have ample indirect experimental verification. But the verification of such assumptions fully deserves such amount of attention as to place it beyond all doubt. The use of only the larger seeds of a stock has also been found to increase the weight of the crop. ("Expts. with Tur. Seeds, Trans. Bot. Soc., Edin., 1876-77." A. S. Wilson.)

Considerations of this kind are certainly worth much more attention than they get. They constitute a portion of what is here called Agricultural Botany. This department of Botany would not concern itself much with any very intimate knowledge of petals, and pistils, and stamens, and anthers; but would address itself more directly to all such questions as affect the most profitable management of farm plants. The present inquiry is an illustration of the sort of work which might be attempted by agricultural botany, and the results which might be accomplished would take the form of profits due to knowledge and carefulness, rather than to increased cost.

But the questions which address themselves to agricultural botany, and which deserve to be answered by conclusive experiments, have usually been altogether subordinated to questions on the

comparative efficacy of manures. The theory of no farm plant has been fully worked out. It is to be hoped, however, that as the new educational impulse advances, a spirit of inquiry may be awakened in those who cultivate our food plants, as to the nature and capabilities of what is daily in their hands. The excellent *clinical* lectures of the chemist of the "Aberdeenshire Agricultural Association" initiated a most important mode of teaching one aspect of cultivation. But while standing by the *beds* of my brassicaceous friends, I could hear certain whispers which, although not pertinent to chemistry, demand attention. We must improve our agricultural botany simultaneously with our agricultural chemistry. For what is the use of adding to our manure and pursuing practices which diminish our crop?

Certain laws regulate the growth and the size of a turnip. The old Romans and the modern Britons have occasionally produced turnips of twenty or thirty pounds weight. And to one who sees turnips only at our shows, it might appear that the average normal weight of these bulbs was eight or ten pounds. But our turnip shows are conducted upon no useful principle. At present they are mere botanical exhibitions. Whether the bulbs shown took each a foot or a yard of a drill to grow upon is of no consequence. The exhibitor selects from any part of his field the requisite number and the largest and best formed plants which he can find. Or he sows a fertile plot at an early part of the season, and raises his show plants under unlimited room. Under this method there lies no organic theory. The exhibition is not a fact of agriculture. The exhibitors act like children trying to astonish each other.

What a farmer professionally wants to do is, not to produce the greatest weight which he possibly can, but the greatest weight which, on any given field in his possession, will yield the highest profit.* If this is not to be done by producing astonishing show roots here and there, but by the heaviest aggregate of smaller roots, then these smaller roots, which give the greatest weight per acre, are really what ought to be presented at our shows. The astonishing roots exhibited at our shows are the products, not of methods of cultivation which may be repeated, but of unknown accidents.

From our turnip shows, as presently conducted, no beneficial impulse whatever in the improvement of the turnip has been received. But if exhibitors would bring forward the turnips grown upon a scheduled length of drill, say 1-1000th part of an acre, such a method would have a clear organic connection with the theory of field cultivation. If upon

* The principle here involved is usually forgotten by those who tell us that our home supplies might be doubled. No doubt some of our worst-farmed land would repay additional outlay; but on our best-farmed land, additional outlay, with the markets of the world open would be responded to—not by diminished crops, but by increased crops and diminished profits. It is all very well to say the produce of the country could be greatly augmented, but the farmer of the land, who alone has the matter in his hands, has no direct interest in augmenting the produce. His interest is to augment or to retain his profits. In a given state of the labour and produce markets, there is a maximum outlay attended by the maximum profit. If this outlay is exceeded, the produce may be increased, but the rate of profit will be diminished. Such experiments as the present have for their object to increase the rate of profit without additional outlay or capital.

the thousandth part of an acre (about 19·36 feet of a 27-inch drill) one man grew 20 plants, another 30, and another 40; if one man grew green-top yellow, another Dale's Hybrid, another Pomeranian Globe, and others other varieties, a full comparison of the products would ultimately lead to all the practical lessons involved in the subject of turnip growing. We should come to know the best variety, and the best interval for singling, with other important facts regarding the size of seeds, the best depth for planting, the least hurtful mode of hoeing, or whatever tends to augment the value of the crop. If an association, wholly devoted to the turnip plant, were to offer adequate prizes for exhibits of the character indicated, farmers would be induced to experiment with all known varieties, with all possible intervals, with seeds of all sizes and ages, and in other ways which experience would suggest, till the full secret of the turnip stood clear to all. A farmer who shows a few unpretending roots, the average of a crop yielding more tons per acre than the picked and astonishing bulbs of his neighbour, and shows how his system of production may be practically repeated, teaches a method of increasing the produce of the country, and proves that the adoption of a better theory is followed by a more profitable result.

SONG OF THE TURNIP.

As Sung at Show Dinners by Old Mains of Brassica.

Let poets rhyme of rose and thyme,
  I sing the turnip crop, sir,
The Bangho'm Swede, the Golden Ball,
  And Skirving's Purple-top, sir,
The Bullocks, yellow, bronze and green,
  As sweet 's a honey-blob, sir,
The Norfolk White, the Mammoth Red,
  And Pomeranian Globe, sir.

I'll spare to lovers lilies white,
  And likewise vi'lets blue, sir,
Give me the flower which busks the byre
  For every call that's due, sir;
To sigh on frail forget-me-nots
  I never could endure, sir,
I nurse my raptures for the plant
  Which pays the bone manure, sir.

Their dahlias, and their hollyhocks,
  And gladiolus tribe, sir,
May pack, with pansies and with stocks,
  To paddocks priests describe, sir;
But raise the ruta-baga roots
  In acres round my lot, sir,
To feast the king of bovine brutes,
  An Aberdeenshire stot, sir.

I wonder that your Tennysons
  Don't see their duty clear, sir,
To jilt their daffodils and sing
  The Swedes, when they appear, sir.
Lor'! 'tis a show, when not a row
  But grasps his neighbour's hand, sir,
Uniting green where nought is seen
  But leaves which hide the land, sir.

My memory dotes on many a field
Of five-and-thirty ton, sir—
When will your feckless phosphates yield
Such bulbs beneath the sun, sir?
Yet could we cope with finger-and-toe,
And lay that fiend, the flea, sir,
We might have something still to show—
The turnip cro—p for me, sir!

TURNIP SINGLING.

Turnip Singling.

In addition to the experiments which I made in turnip singling in 1877 and 1878, I made a few in 1879, the results of which have now been ascertained. I may repeat that the conclusions derived from 1877 and 1878 were that, in ordinary cultivation, intervals of 6 inches between the plants will give a heavier crop than intervals of 8, 9, or 12 inches. Two plants on 12 inches will in general be heavier than one; four plants on 24 inches will be heavier than three; six plants on 36 inches will be heavier than four. Exceptions will arise here and there; but it is evident that there must be some interval which will in general give the heaviest crop, and that interval is probably somewhere near 6 inches. If part of a drill is singled to intervals of 1 inch, part to intervals of 2 inches, and so on up to intervals of say 16 inches, the maximum crop must fall somewhere between these extremes. On one side of the maximum the plants become less and less, and the crop lighter and lighter; and on the other side the plants become larger and larger, but the crop also becomes lighter and lighter. The problem of singling is to find where the maximum falls.

On the 13th June, 1879, I sowed with the tin box on two adjoining drills 27 inches apart, in the field, six common varieties of turnips. They brairded evenly, and there was no fly; but it was evident that certain of the varieties were growing faster than others; and it turned out that those which grew the fastest attained the greatest ultimate weight. The difference in energy of vitality in different varieties, or the difference in capacity of absorbing and assimilating food, is a fact which ought to be kept in mind in comparing manures intended to give a start to the crop.

They were singled on the 28th July to intervals of 6 inches and 1 link (7·92 inches); one part of each drill being 6-inch intervals and the other part link intervals.

The length of drills was 301 feet; so that on the 6-inch intervals 602 plants were left, and on the link intervals 456. From the 6-inch intervals 9 plants disappeared, and from the link intervals 7 plants, or, in each case, only about 1½ per cent., so that practically the whole process of growth was accomplished in the true competing intervals.

They were pulled and weighed on 2nd February. A few of the tap roots were slightly affected by finger-and-toe, the clubs being quite fresh, recent, and solid, and showing that the fungus goes on working through the winter. In the whole quantity 8 bulbs were rotten; but as they had attained to full growth before decomposition set in, the adjoining intervals were not affected. The average weight of plants below is the average of the sound plants, including tops and tails free of all earth. The weights per acre are

derived from the full numbers of plants, 38,720 for the 6-inch, and 29,333 for the link intervals, multiplied by the average plants. The actual weight on the acre, however, in the 6-inch intervals, averaging the six experiments, is only 2 3-10ths per cent. below the theoretical weight, and in the link intervals 2 2-10ths per cent.; probably the actual crop seldom approaches so closely to the full theoretical weight.

RESULTS OF SINGLING TURNIPS, CROP 1879.

	Average weight in 6-inch intervals.	Average weight in link intervals.	Weight per acre in 6-inch intervals.	Weight per acre in link intervals.
	lb.	lb.	tons.	tons.
1.—Lincolnshire Red ..	1·19	1·25	20·57	16·30
2.— Pomeranian White ..	·92	·90	15·90	11·79
3.—Champion Green - Top Hybrid ..	·48	·57	8·30	7·46
4.—Champion Purple - Top Hybrid ..	·67	·73	11·58	9·56
5. — Lancashire White ..	·68	·79	11·75	10·35
6.—Improved Purple - Top Mammoth ..	·91	1·29	15·73	16·89
Averages	·81	·92	13·97	12·07

It is thus seen that in five of these experiments the weight is in favour of the 6-inch intervals, and in one of them in favour of the link intervals; the average of the whole being 2 tons per acre in favour of the 6-inch singling. Probably, therefore, a heavier crop will in general be secured from 6-inch intervals than from any other.

A few other points may be noticed. As indicating, though not with sufficient

generality, the productive power of '79 compared with '78, we have the average plant in the 6-inch intervals of '79 weighing ·81 of a pound, while in '78 it weighed 1·84 pound, or rather more than double the weight of the crop of '79. Or comparing a single variety; the Lincolnshire red globe in the 6-inch intervals in '78 weighed 2·90 lb., while in '79 it weighs 1·19 lbs., the proportion being 100 to 41. In this case the land and manuring were about the same in both seasons, and it shows how much depends upon elements of growth over which agricultural science has as yet acquired no control; and may give a hint to the impatience with which fully verified results are expected from experimenters.

The difference in weight between one variety and another, under nearly equal circumstances, is also noticeable. The Lincoln red produces 20·57 tons where the green-top produces but 8·30 tons. Both in '78 and '79 the Lincoln red gives by far the heaviest crop of any variety used. Purple-top Mammoth was sown in '78 and '79, and in both seasons is next in weight to Lincoln red.

It is thus obvious that in experiments of this kind different intervals can be properly compared only when the same variety of turnips is used in them. An experimenter contending for the superiority of 9-inch intervals and using Lincoln red, would beat another using any one of many other varieties in 6-inch intervals.

The chemistry of these varieties of turnips is not any part of this inquiry. But the differences in return from the same cost make it clear that botanical considerations are of capital importance in manurial experiments.

Where different turnip manures are to be compared, unless the same variety of turnips is used in all cases, and perhaps unless the same stock of seed is used, the results can have no value. The proximate constituents in green-tops and purple-tops do not seem to be very different; but the difference in gross produce is obvious to all. And it may be suspected that until chemical analysis, agricultural knowledge, and physiological insight have advanced to a surer position, the mere gross weight of crop will continue to be a higher certificate than a doubtful preponderance of protein compounds. The pedigree wheat and oats, cultivated by Captain Hallett, are of inferior quality, that is, the oats has a low percentage of kernel and the wheat a defective colour; but the contention is, that the inferiority of quality is outvalued by superiority of quantity. In like manner it is a question deserving solution, whether the crop of that variety of turnips producing the greatest gross weight is or is not of greater value than the crops of varieties of better quality, but of lower productive capacity?

A. Stephen Wilson.

"droit pois," or *right weight* of the proposed Norman standard; and that the "sterling" spoken of was the base, not of the King's money, but of the King's measure; "genis ponderis; ane kinde of wecht."

The conclusions arrived at in the three papers are based on original observations and experiments.

REVIEWS OF THE BOOK.

The Scotsman.

"On looking at this little volume * * * we fancied at first sight it belonged to that class of works which tries to spiritualise the Bible, and put into them the crotchets of a Biblical crotcheteer, the most virulent of the species. On reading the work we found our expectation had been quite erroneous; we found that we had to do with a painstaking, well-informed man, who devoted a great deal of study and botanical, agricultural, metrological lore to three subjects. * * * The Parable of the Sower affords scope for exhibiting the writer's acquaintance with cereals and their cultivation. The conclusion, interesting probably to Biblical readers, arrived at is that the returns from the good ground were not aggregate returns from whole fields, but that they were returns from individual seeds. The minute account of Eastern agriculture and averages of production seems more valuable and more correct than this little piece of exegesis. * * * We observe that he explains the expression 'troy weight,' first found mentioned in 1393, differently from what is commonly met with. *Octroi* is the usual derivation, but, according to Mr Wilson's view, "the word *troi* is not derived at all, it is simply a different way of writing droit," the old monogram on weights was DR, afterwards becoming TR. Certain standards were 'droit pois,' 'right weight,' hence 'troy weight,' meaning thereby the approved standards whether of money weight or commercial."

The Daily Free Press.

"The inquiries of Mr Wilson into the different parts of his threefold subject are marked by exceedingly exact observation and ingenious and accurate reasoning, all the available lights from history, sacred and profane, being called in to show that in all probability the 'seven ears' of Pharaoh's dream, &c. * * In the Botany of the Parable of the Sower an equally interesting and exact discussion is carried through; the expressions thirty, sixty, and an hundred-fold being brought into close relation with the facts of natural history, as it concerns the growth of wheat springing from seeds of greater or less primary vigour cast into soils more or less favourable to their development. 'The Botany of the King's Measure' concerns itself with the question—what is the

weight of thirty-two grains of wheat? And here, Mr Wilson's known skill as an accurate experimental observer has enabled him to make a real contribution to the history of British metrology. * * * The work is illustrated with several beautiful plates from the author's own drawings, and though so condensed in form as to assume in parts a good deal of the form of a text book, it is altogether a remarkable example of careful research and observation in a field of curious and abiding interest."

The Liverpool Albion.

"That large class of readers who are accustomed to choose books solely by their titles are likely to pass over this little book as probably uninteresting. They will make, as they frequently do, a great mistake. No doubt a student of Botany will welcome the information here collected on the growth and productivity of the cereals, but very few general readers will find the scientific details beyond their comprehension. * * * In the second essay, more especially, there is displayed not merely soundness of reasoning and accuracy of observation, but a felicity of phrase which strikes us much. * * * We have no space to give an account of the third essay, which, though on a less attractive subject, is conceived and carried out in the true scientific spirit—a spirit which shirks no labour in the discovery and illustration of truth."

The Inverness Courier.

"The book is useful as affording illustrations of Scripture incident and teaching. The explanations, however, might have been given in a simpler and clearer form. The third paper enters into numerous details as to English measures, and will be interesting to those who have time to follow out the subject."

The Guardian.

"It is always pleasant to come across a really 'thorough' book, whatever the subject of it may be. And this praise can conscientiously be given to *The Botany of Three Historical Records* (Edinburgh: Douglas), by Mr. Stephen Wilson."